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MEMORANDUM

ON THE

ESTABLISHMENT OF A FACTORY FOR IMPREGNATING PINE SLEEPERS FROM THE NORTH-WEST HIMALAYA WITH METALLIC SALTS.

BY

DR. H. WARTH,

COLLECTOR OF INLAND CUSTOMS, ON SPECIAL DUTY.

Dated the 14*th September* 1878.

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[NOTE.—All data have been given in English weights and measures.]

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I.—GENERAL REMARKS.

1. THE large demand for railway sleepers has given rise to a number of methods for preserving timber from decay, most of which are still in use. Pneumatic creosoting is the process chiefly employed in England. Heavy coal-tar oils, which contain a proportion of creosote or raw carbolic acid, are introduced under great pressure into the wood, from which the air has previously been exhausted. The tar oils, by keeping off moisture, and creosote or carbolic acid by its great antiseptic properties, preserve the wood to such an extent that prepared sleepers last two or three times as long as if they were employed in their natural state. On the Continent of Europe, other methods besides creosoting, based upon the antiseptic properties of salts of zinc, copper, and mercury, are used.

2. Timber which has been recently felled is impregnated in the round with sulphate of copper by Boucherie's process. A solution of that salt is introduced under moderate hydraulic pressure into the stem, and, whilst gradually filling up

the pores of the wood, it drives out the sap before it. Boucherie's process can only be employed within a short time after the trees have been felled; and though it is used in the well-stocked and compact forests of Europe for large timber which is afterwards cut into railway sleepers, it would not be applicable for railway sleepers in India; because the sleepers cannot be impregnated by it after they have been cut from the log, and it would thus become necessary to erect a factory in each locality where the trees are cut. In the incompletely stocked forests of India, this would spread the operations over too large an area; and, on this account, this method is probably not adopted for railway sleepers in this country. It has, however, been reported that timber which, immediately after felling, is immersed in water or is floated, remains for a considerable time fit for impregnation by this process. Experiments will have to be made, and if this is found to hold good in India, it may be found practicable to impregnate timber by Boucherie's process, after it has been floated. An unavoidable drawback will, however, always remain, namely, that the process is wasted upon slabs and log ends. In Europe its application is found most profitable in the case of telegraph-poles and half-round sleepers.

3. Corrosive sublimate, a highly antiseptic and poisonous compound of mercury, is applied to ready-cut sleepers by soaking them for a fortnight in a solution of it. Though the salt does not penetrate to the interior of the sleeper, it has been found to afford a very satisfactory protection against decay, both of the interior and exterior portions of the wood. This method has long been, and is still, in use on Baden, Bavarian, Würtemberg and other German railways where pine-wood is impregnated with this salt; the results on these railways have been considered to be satisfactory.

4. When applying the other salts, chloride of zinc and sulphate of copper, to ready-cut sleepers, the pneumatic process is found to be required to give full protection against the early decay of the inner part of the wood. The sleepers are placed in large iron or copper cylinders, and subjected first to a partial vacuum, and then to a bath of the solution, which, under high pressure, permeates every part of them. The application of chloride of zinc is most in vogue at the present time. It is employed for hard oak-wood, as well as for the much less durable pine and beech. The railways in Hanover, Brunswick, Westphalia, Mecklenburg and some of the Austrian and Bavarian lines, make use of the zinc process for their sleepers. In England, though sleepers are only treated with creosote, the zinc process (Burnettizing) is used for the preservation of timber in cases where creosote is inadmissible on account of its smell, colour, and inflammability.

5. Sulphate of copper in solution is applied by the pneumatic process in copper cylinders on the Alta Italia railway of Lombardy and on the Vienna-Trieste railway in Austria, on the Berlin-Hamburg and Magdeburg-Wittenberg lines in Germany, and it is used at several places in France.

6. Good results have been obtained from all these processes, and they are all in use. The choice amongst them depends mostly upon the price of the materials, the cost of the processes, and the nature of the timber on which they are to be employed. The experience gained in Germany and Austria to 1868 has been compiled and published; later data have not been brought together in a systematic manner, but whatever information is available on the subject is embodied in the following remarks. In 1868, a conference of Engineers from all German and Austrian railways was held at Munich. The administrations of the different railways had been requested to report on the durability of the different kinds of sleepers used by them. Their reports have been published in a periodical entitled "Organ für die Fortschritte des Eisenbahnwesens, 1869." Of the lines represented at the conference, sixteen had used sleepers in their natural state, while twenty-four had employed various processes of impregnation.

7. The following results are reported regarding the durability of unimpregnated sleepers. A few entries which related to small quantities of sleepers (less than 25,000) have been omitted.

Durability of Timber Sleepers not impregnated.

Line of railway.	Description of Timber.	Number of Sleepers.	Percentage of renewals		
			After 10 years.	At a later (in some cases earlier) period.	
				Years.	Percentage.
Altona-Kiel	Oak.	167,000	6·71	24	96·19
Elizabeth bahn	,,	259,332	...	8	43·27
Hanover	,,	165,265	14·92	19	72·42
Hessen Nord bahn	,,	192,000	16·7	21	89·5
Main-Neckar	,,	101,760	46·4	12	68·6
Saarbrück	,,	183,081	80·0	...	...
Preussen. Ost bahn	,,	80,273	...	6	5·7
Berlin-Potsdam-Magdeburg ...	,,	180,204	8·12	20	75·4
Sachsen West bahn	Spruce	26,720	...	7	100
Süd-Norddeutsche-Verbands ...	,,	233,640	...	8	94·6
Elizabeth bahn	Scotch fir	289,530	...	8	59·53
Oppeln-Tarnowitz	,,	79,200	91·9	11	98·9
Leipzig-Dresden	,,	93,543	73·7	11	86·4
Sachsen West bahn	,,	120,835	84·5	11	100
Schleswig	,,	146,800	75·5	13	90·7
Warschau-Wien	,,	152,500	...	6	63·5

The results of these figures are summarized as follows in the report :—

	Percentage of Renewals		Estimated Life.
	After 5 years.	After 10 years.	Years.
Oak	4·5	31·1	13·6
Spruce	48·8	.....	4·2
Scotch fir	13·6	67·7	7·2

From other experiments it is known that beech unimpregnated, only lasts 3 years, and that of sleepers of that wood 100 per cent. are renewed after 5 years.

8. Regarding the impregnation with creosote under the pneumatic process, it was reported at the conference of 1868 that in the Köln-Minden line of 67,678 oak sleepers thus impregnated, 0·78 per cent. had been renewed after 10 and 8·60 per cent. after 13 years. Creosote is used with perfect success on some of the largest railways in Germany, amongst others on the Rheinische Eisenbahn, the impregnating apparatus being at Nippes near Cologne, on the Hessische Ludwigs-bahn (apparatus opposite Mayence on the Rhine), and in Alsace. The Köln-Minden and some of the Bavarian railways also used creosote formerly, but have abandoned it on account of its cost; they have now substituted chloride of zinc. In England, as already mentioned, creosote is the chief substance used for railway sleepers, and the confidence in its efficacy is unabated. In India, it may be assumed that imported creosoted pine-sleepers from England have a life, on the average, of at least fifteen years.

9. The price of creosote may be said to average £3 per ton in Germany.

Beech and pine-wood are generally made to take up 10lbs. or 1 gallon per cubic foot, and oak 3lbs. per cubic foot. The cost of the process may be put down at 1*d.* per cubic foot, so that the total cost of the impregnation per cubic foot stands as follows :—

	Cost of process.	Cost of material.	Total.
Oak	1*d.*	1*d.*	2*d.*
Beech and pine	1*d.*	3·2*d.*	4·2*d.*

The cost of the process as here stated is calculated on the assumption that the machinery is kept constantly employed on full work, and the rate includes an allowance for interest on capital, and also for depreciation.

10. Corrosive sublimate, employed by soaking in wooden tanks, gave the following data :—

Durability of Sleepers soaked in corrosive sublimate.

Line of railway.	Description of timber.	Number of sleepers.	Percentage of renewals	
			After years.	Per cent.
Baden	Oak	7,800	7	1·28
„	Scotch fir	31,000	7	3·7
Rhein-Nahe	Beech	.....	9	3·26
„	Oak	.....	9	3·26
„	Scotch fir	.....	9	5·89
„	Spruce	.....	7	0·08

When the Baden railways were first built, a commission of engineers from Baden went to England, where they became acquainted with the Kyanizing process; and, on their return in 1840, they introduced it on the lines built by them. On account of the great expense, a more economical process (boiling in a solution of chloride of zinc) was introduced in 1853, but in 1859 the Railway Administration returned to corrosive sublimate, as sleepers thus prepared were found perfectly sound after twenty years. Since then an average duration of thirty years on particular portions of the line has been noticed.

The process has been found to be particularly beneficial in the case of sleepers of spruce and silver fir. The favorable results obtained by the application of corrosive sublimate have induced other lines in Nassau, Hessen, Bavaria and Würtemberg to adopt the process.

11. Corrosive sublimate is an expensive material: £350 per ton may be put down as the average cost, but it is used in a weak solution containing only 0·66 per cent. of the salt; it is taken up by all woods alike at the rate of 0·066 lb. of the salt per cubic foot. The cost of the process is estimated at 0·5*d.* per cubic foot, and accordingly the cost of the entire impregnation is for all kinds of wood 3*d.* per cubic foot, of which 2·5*d.* represents the cost of the salt.

In India impregnation with corrosive sublimate would not cost more than 2·4 annas per cubic foot, or 8½ annas per sleeper of 3·47 cubic feet. There is no reason to anticipate less favourable results from the impregnation of pine-wood with this salt in India, than have been obtained in Europe; and it will therefore, if the plans here proposed are accepted, be proper, as an experimental measure, to impregnate sleepers of *Pinus longifolia* with corrosive sublimate in India.

12. The following are the results as reported at the Munich conference of mere soaking in a solution of chloride of zinc :—

Line of railway.	Description of timber.	Number of sleepers.	Percentage of Renewals		
			After ten years.	After a longer (or shorter) period.	
				Years.	Per cent.
Altona-Kiel	Oak	140,851	0·00	16	5·89
Baden	„	11,390	13·76	11	18·9
Köln-Minden	„	19,033	...	11	0·01
Altona-Kiel	Scotch fir	29,317	...	5	50·
Baden	„	70,000	39·6	11	44·3
Sachsen Ost bahn	„	...	...	8	5·
Altona-Kiel	Spruce	3,899	91·0	12	98·
„	Beech	1,527	...	8	25·5
Köln-Minden	„	4,577	29·74	11	46·28
Hessen Nord bahn	„	25,761	...	5	85·0

The returns of the Köln-Minden railway do not state whether the sleepers were merely soaked or were subjected to the pneumatic process. The Baden and the Hessen Nord bahn boiled the sleepers in the solution by passing heated steam through the tanks; the other lines applied the solution either cold or at a lower temperature than the boiling-point. The results are not favourable. The durability of oak-sleepers has not been increased by the process, and, in the case of Scotch fir, spruce, and beech, the results are unequal. The process is not much used at present, and it is not recommended for India.

13. The following results are recorded with regard to the pneumatic process with chloride of zinc:—

Line of railway.	Description of timber.	Number of sleepers.	Percentage of Renewals			Strength of solution by measure.
			After ten years.	At a later period.		
				Years.	Per cent.	
Brunswick ...	Oak	6,222	0·34	12	1·69	1 in 30
„ ...	„	2,877	1·46	10	1·46	1 in 50
Hanover ...	„	168,690	2·20	13	11·50	not stated.*
Brunswick ...	Scotch fir	600	4·3	15	18·0	1 in 30
„ ...	„	78,385	1·93	12	4·87	1 in 30
„ ...	„	28,772	1·19	10	1·19	1 in 50
Hanover ...	„	155,755	1·10	11	1·30	not stated.*
Brunswick ...	Beech	600	7·2	15	42·0	1 in 30
Hanover ...	„	81,002	4·90	13	19·68	not stated.*

* It is probable that the sleepers on the Hanover lines were impregnated with the strong solution (1 in 30), but this is not expressly stated.

With the exception of two small batches of 600 sleepers each, laid down on the Brunswick lines, the results are very favourable. It may be assumed that the durability of oak is increased by this process from 13 to 19, that of Scotch fir from 7 to 17, and that of beech from 3 to 15 years. In the case of Scotch fir, it will be noticed that the weaker solution (1 in 50) gave a better result than the stronger solution (1 in 30). This fact, which at first sight is very remarkable, is explained by the chemical action of chloride of zinc upon wood in contact with iron. A solution of 1 in 30 by measure is a very strong one. It contains by weight not less than 5·23 per cent. of chloride of zinc of commerce, equal to 1·31 per cent. of metallic zinc.

14. On the Brunswick lines a strong solution containing 1 part in 30 by volume, of the chloride of zinc of commerce, which contains 25 per cent. of metallic zinc, was originally used. In 1857 it was observed that out of 459 beech-sleepers, which had been laid down in 1852, 41 per cent. were more or less injured, but they were not all injured to such an extent as to require renewal. The injury was confined to the places where the impregnated wood was in contact with the iron nails and plates. Starting from these points of contact to some distance in the direction of the fibres, the wood was discoloured and soft and had lost its consistency, the nails had become loose and the sleepers were useless, though they were otherwise well preserved.

Pine sleepers impregnated at the same time with the same strength of solution, showed a more favourable result, and very little injury was observed in the case of oak-sleepers.

To obviate this injurious effect of the chloride of zinc upon the wood in contact with iron, a weaker solution (1 in 50) was used after 1857, and has been used ever since with excellent results. On the Hanover lines the same process was used in 1851 with a similar strength of solution. The sleepers laid on that line (oak, pine, and beech) showed no signs of injury, but following the example of the Brunswick lines, the strength of solution was reduced to 1 in 60. This solution is used at present, and contains 0·66 per cent. of metallic zinc by weight or 2·64 per cent. of chloride of zinc of commerce.

15. The chloride of zinc of commerce is a heavy fluid, containing 25 per cent. of metallic zinc. Its price may be put down on an average at £10 per ton. The quantity taken up per cubic foot in the case of a solution of 1 part (volume) in 60 is 0·2lb. per cubic foot for oak, and 0·4lb. for beech and fir or pine-wood. On several lines, however, the quantity of chloride of zinc taken up per cubic foot is much larger. Thus, Heusinger von Waldegg, in his excellent work "Handbuch für specielle Eisenbahntechnik" (Leipzig, 1873), page 154, gives data from which it appears that the Westphalian line put 0·84 and the Köln-Minden line 2·58lbs. into a cubic foot of Scotch fir timber. The cost of the process being the same as with creosote, the total cost of impregnating one cubic foot is as follows; on the assumption that one cubic foot takes up 0·2lb. and 0·4lb. of chloride of zinc respectively :—

	Cost of process.	Cost of material.	Total.
Oak, per cubic foot	1*d.*	0·2*d.*	1·2*d.*
Beech or pine, per cubic foot	1*d.*	0·4*d.*	1·4*d.*

The process, therefore, is much cheaper than the employment of creosote, and consequently several railways have lately substituted chloride of zinc for creosote, as the results regarding the durability of sleepers impregnated with creosote were not materially better than those obtained on the Hanover and Brunswick lines with chloride of zinc. The chief lines which have lately substituted chloride of zinc for creosote are the Köln-Minden railway in Prussia and some of the State railways in Bavaria.

16. The following are the results reported at the Munich conference of soaking sleepers in a solution of sulphate of copper. This process is known as Margary's process :—

Line of railway.	Description of timber.	Number of Sleepers.	Percentage of Renewals		
			After ten years.	After a longer (in some cases shorter) period.	
				Years.	Per cent.
Lübeck-Büchen	Scotch fir	60,000	5·8	17	69·0
Preussen. Ost bahn ...	„	158,140	27·02	14	95·1
Berlin-Stettin	„	207,248	...	8	9·5
Berlin-Potsdam-Magdeburg ...	„	36,640	12·1	16	66·2
Preussen. Ost bahn ...	Spruce	198,020	...	7	96·1

The temperature of the solutions employed is not stated. The strength varied on different lines; on the Berlin-Stettin line a strong solution, containing six per cent. of the salt (1·5 per cent. of metallic copper), was used, and the results on that line have been very favourable.

Besides the lines mentioned in the list given above, the process was also used on the Westphalian State Railway. The sleepers were dried artificially, and then soaked in a solution containing 4 to 5 per cent. of the salt, but there is no report of the durability of the sleepers thus treated. With the exception of the Berlin-Stettin line, where, as explained, a strong solution was

employed, the results of soaking sleepers in a solution of sulphate of copper are not very favourable, but they are better than the results obtained by soaking sleepers in a solution of chloride of zinc.

17. Boucherie's process is employed largely in France, where the results are said to have been very favourable. In Germany it is chiefly used to impregnate telegraph-posts. There is a large factory at Biberach Zell in the Black Forest in Baden territory, where posts of spruce and silver fir are impregnated. The solution used in this process contains from 1 to $1\frac{1}{2}$ per cent. of sulphate of copper.

At the Railway Conference of 1868, the experience gained in the employment of this process on two lines was reported as follows:—

Hessen. Nord bahn	... beech	75,000 sleepers.	In 7 years	38·6	per cent. removals.
Vienna-Trieste	... „	20,238 „	„ 7 „	13·5	„ „ „

It has also been used on several lines in Bavaria and Saxony. In Bavaria, however, it has been given up.

Some statements are recorded in France of the injurious effects of the sulphate of copper upon the wood in contact with iron nails, but Boucherie's process is used on a large scale in that country, and whatever the injurious effect may have been, it does not seem to have interfered with its efficacy. The adoption of this process is not, however, recommended at present, as the apparatus must be set up in the forest; and the forests to be worked for sleepers in India are not, as a rule, sufficiently compact and rich in mature timber to render such arrangements feasible. Moreover, the impregnated sleepers must be floated, which would probably have the effect of diminishing the quantity of sulphate of copper in the wood. It will be different if, as already stated, experiments should show that timber which has been floated, can be impregnated by this process.

18. The impregnation with sulphate of copper by the pneumatic process is practised on a large scale on several lines, as stated above in paragraph 5, and it is chiefly used to impregnate beech and pine.

On the Vienna-Trieste line, only beech is employed for sleepers. Formerly Boucherie's process was used, but since 1865 the pneumatic process has been substituted, and under it 120,000 beech sleepers are impregnated annually with sulphate of copper. As far as the experience has gone, the sleepers thus impregnated have been found to attain the durability of unimpregnated oak, which means that their life has been raised from 3 to 13 years. No data regarding the durability of sleepers prepared by this method were reported at the conference of 1868, but from the data otherwise recorded, the conclusion is justified that the life of Scotch fir has been increased from 7 to 16 years.

The data recorded regarding the durability of the sleepers treated by this process are incomplete; but, as far as they go, they seem to show that it is somewhat less effective than the pneumatic process with chloride of zinc. But this cannot be regarded as finally established.

The extensive use of the process with good results on a wood so perishable as beech, proves clearly its great efficacy.

On the Berlin-Hamburg line the solution has been used with a varying strength containing $1\frac{1}{2}$, 2, and 4 per cent. of sulphate of copper. At Salluch on the Vienna-Trieste line a solution containing 2 per cent. of the salt has been employed. On the Berlin-Hamburg line, after the air has been exhausted in the usual manner, the solution is forced into the wood under hydraulic pressure, the tanks containing the fluid being raised 44 feet above the cylinders.

The cost of sulphate of copper is £30 per ton, and the cost per cubic foot of impregnated wood stands as follows, under the assumption that the wood (beech and pines) takes up 0·3lb. of the salt per cubic foot:—

Cost of material	1*d.*
„ „ process	1*d.*
Total ...	2*d.*

The process, therefore, is somewhat more expensive than the pneumatic process with chloride of zinc, while less precise data are available regarding the result. But sulphate of copper is a more poisonous substance than chloride of zinc, and therefore its employment in India for impregnation under the pneumatic process is recommended by way of experiment.

19. An account has lately been published of a new patent process for seasoning and preserving timber. It is necessary to refer to this new process, because it has been declared superior to any of the old methods; and if this were really the case, it would not be advisable to propose works on the old plan. The inventor is Mr. D. Gardner of the firm of Messrs. A. Gardner & Son, Cabinet-makers, 36, Jamaica Street, Glasgow. A report on the subject appeared in the Journal of Forestry, London, December 1877, at page 526. This report says that mahogany subjected to the patent process was found fit for cabinet-work within three weeks from its being cut from the log. Norway props were used in a coalpit, some of them unprepared, and the rest prepared by the new process, and were examined after thirteen months. The unprepared timber was completely destroyed, while the prepared timber was quite sound. Some sleepers were also tried, and showed a similarly good result. The process is also said to strengthen the timber. Experiments with pitch pine, Scotch fir and white pine showed an increase of one-half in the crushing weight as the result of the process.

The process is described as the steaming of the wood while closely packed in an open wooden tank for 24 hours with ordinary steam, and for another 24 hours with a mixture of steam and a chemical substance which is a secret. It is also alleged that, by subjecting the wood to a second chemical process, timber which it is required to render specially durable could be rendered absolutely proof against decay through the filling up of the pores with chemicals.

The process is said to be used by numerous classes of consumers including railway engineers. It does not discolour the wood.

The account further states that the process affords a ready means for impregnating the timber with liquid chemicals, which, whilst preserving the wood from decay, renders it proof against the attacks of *Teredo navalis*, *Limnoria*, and white-ants.

20. The above is all that can be ascertained from the very slight account given in the Journal of Forestry regarding the process, yet it is sufficient to enable us to form some estimate of its worth. Apparently the whole benefit derived from the process is merely due to the steaming, and the admixture of other substances with the steam has no considerable effect. It is probable that some substance, which may possibly tend to preserve the timber, was added to the steam; but it is not likely that the main benefit of the process was derived from the addition of this substance, the nature of which is made a secret. It is unlikely that the process effects more than pneumatic impregnation combined with artificial or complete natural seasoning of the wood.

The preservative power of the new process, as demonstrated by the above mentioned experiments, is fully accounted for by the steaming alone. Forty-eight hours' full steaming with subsequent drying is sufficient to season the wood thoroughly by extracting all the sap. Wood thus freed of its sap will have a considerable durability, though it will not be quite equal to wood which has also been impregnated with antiseptic substances.

The only result obtained by the process which remains unexplained is the increased strength of the timber. However, the report only shows that the crushing weight of certain small specimens was increased 50 per cent. No data are given regarding either the tensile or the transverse strength, and it does not appear whether these have increased or diminished. It is not impossible that the increased resistance to a crushing force may be due to the seasoning of the wood effected by the process, and not to the admixture of the unknown substance, and that thus, any other method of seasoning, including the ordinary drying process, would have had the same effect.

Under these circumstances, there is no ground to believe that this process will be found more effective than the pneumatic process, and, until more is

known regarding it, it would not be advisable to suggest its employment. If, however, an impregnating factory is established in India on the plan here suggested, experiments to improve the durability of timber by steaming can easily be made.

II.—Experience of impregnated woods, and experiments made in India.

21. Creosoted pine-sleepers from England are to a large extent imported into this country. No doubts are entertained regarding the general suitability of these sleepers for the climate of India. If there have been failures, they only show that even the best preservative process is of no avail where the necessary precautions are not taken.

Colonel Kennedy, Secretary to the Government of Bombay, Public Works Department, Railway Branch, in a letter dated the 18th January 1870, says: "Imported creosoted pine-sleepers, when thoroughly impregnated, were found as durable as any other sleepers that could be purchased."

A report from Madras, dated the 18th December 1869, by Major Shaw Stewart, Consulting Engineer for Railways in Madras, states that on the north-west line of the Madras Railway 30 per cent. of the imported creosoted pine-sleepers decayed within 12 months, whereas on the south-west line all creosoted pine-sleepers that were put down were in good condition at the end of $3\frac{1}{2}$ years, and some had lasted for more than 6 years. The sleepers of this description which have been used on the Great Southern of India Railway are still in good order after the lapse of 7 years, and in some cases after 9 years. The great difference in the behaviour of these sleepers is ascribed to the greater or less care that was taken with the impregnation, and to the different descriptions of ballast, sand being the best.

22. Mr. Sibley, Chief Engineer of the East Indian Railway, wrote on the 28th March 1870 as follows:—

"The imported creosoted fir-sleepers have generally given entire satisfaction. The efficacy of impregnation with creosote has been doubted in the case of dry soils, but in some samples of triangular sleepers recently taken out of the road, owing to the section having been reduced by the destructive effect of packing, the inside wood was found to be quite sound, and the odour of the creosote still pungent; these had been down some 13 years just above Allahabad."

It may generally be said that up to the present time, creosoted sleepers imported from England have lasted remarkably well in India.

23. No sleepers impregnated with other substances than creosote, appear to have been imported into India, at least no facts regarding such are on record.

24. Various attempts have been made to impregnate timber in India, but they have either not led to any satisfactory result, or else the conditions have not been sufficiently favourable to admit of the work being continued.

The following is a brief account of the experiments made in different localities, as far as they have been recorded in official documents.

25. At Bally near Howrah, an apparatus for impregnating railway sleepers with creosote was set up by the East Indian Railway, and was in existence in April 1854. Details are recorded of the cost of the process for one week, and during that week's trial the rate per sleeper, measuring about $3\frac{1}{2}$ cubic feet, was, as nearly as can be ascertained, $7\frac{2}{3}$ pies. The cost of the creosote is not included in this amount; it was put down at 4*d.* per gallon. Further experiments were made regarding the amount of creosote which different kinds of wood could take up. It was ascertained that several kinds of hard timber absorbed very small quantities of the oil. Sal, for instance, took up only 1lb per cubic foot, while sissoo took up $3\frac{3}{4}$lbs. per cubic foot. The cost of creosote for a sissoo sleeper was therefore 4·16 annas, and, including $7\frac{2}{3}$ pies or 0·64 annas for the process, the preparation of each sleeper cost 4·8 annas.

This low figure is fully accounted for by the fact that nothing whatever is put down for interest of capital, depreciation of plant, repairs, salary of officers, transport of sleepers to the factory, and other items which must be taken into account in ascertaining the actual cost. Apart from this, the quantity of creosote absorbed was only one-third of what ordinary pine-wood has been found to absorb in Europe. The cost of the experiment at Bally cannot, therefore, afford any data bearing upon the works now proposed for Upper India.

26. Mr. Sibley, the Chief Engineer, East Indian Railway, in a letter addressed to the Chairman of the Board of Agency, East Indian Railway, dated the 28th March 1870, alluded to the experiments at Bally. He said the general results had been that the jungle-woods of Lower Bengal were too hard and dense to absorb creosote to any beneficial extent. In a subsequent letter dated the 30th April, he says: Nothing further of any moment has been done at Bally since 1863.

It thus appears that the process was given up, because the hard woods were not adapted for impregnation, and no suitable soft woods were available in large quantities. Moreover, the creosoted pine-sleepers from England were probably cheaper.

27. All the available information about another apparatus at Sahibgunge is found in the following letter, dated the 17th March 1871, from the Chief Engineer of the East Indian Railway, to the Chairman of the Board of Agency:—"There is one new spare creosoting apparatus at Sahibgunge, which this Company will sell for Rs. 30,000." In a letter dated the 23rd March 1871, he says the apparatus consisted of two cylinders, 34 feet long, 6 feet diameter, capable of bearing 150lbs. pressure per square inch.

28. The East Indian Railway Company also erected an apparatus on the pneumatic principle at Aligarh to impregnate sleepers of *Pinus longifolia* with creosote. It cost £1,750 at Calcutta.

Mr. Sibley, in his letter already quoted of the 28th March 1870, makes the following reference to Aligarh:—

"In 1869, a number of chir sleepers (1,400) from British Garhwal were impregnated at Aligarh with Burmese petroleum, and 13,500 were subsequently impregnated with creosote."

Mr. W. C. Furnivall, Superintending Engineer, Rajputana State Railway, in a report on the process of creosoting sleepers at Aligarh, dated the 6th May 1870, gives the following additional information:—

The process was beneficial, though at that time it was too early to speak with any certainty as to the results. The apparatus consisted of one cylinder 70 feet long, 6 feet in diameter, holding 300 sleepers. The estimated cost of the whole apparatus was Rs. 28,000. The following are the details of the cost of the process per sleeper (broad-guage):—

	Rs.	A.	P.
4¾ gallons of creosote landed at Aligarh, at 6½ annas per gallon...	1	15	0
Labour in staeking and withdrawing sleepers, at Rs. 5 per 1,000	0	0	10
Percentage of engine expenses and firing	0	2	2
Total ...	2	2	0

29. In a report by Mr. H. Prince, Superintending Engineer, Light Railways, North-Western Provinces, dated the 18th January 1874, it was stated that chir-sleepers treated with creosote at Aligarh appeared to be lasting very well, while those which remained a long time in the stacks without preparation were rotting with marvellous rapidity. No steaming or artificial drying was practised, and the result obtained would seem to indicate that, even without this, the process is sufficient to increase the durability of this otherwise very perishable timber.

The cost of the process per 100 sleepers is as follows, one gallon of creosote being forced into every cubic foot, and each sleeper containing 3½ cubic feet:—

	Rs.	A.	P.
350 gallons of creosote, at 4 annas per gallon	87	8	0
Labour (loading and unloading)	2	8	0
Engine-driver, oil and coal, say	2	0	0
Total Rs. ...	92	0	0

or nearly Re. 1 per sleeper, or about 4 annas 9 pies per cubic foot. The apparatus was charged 3 times a day, each charge consisting of 216 sleepers.

The wide difference between these two estimates is mainly due to the fact that Mr. Prince assumes a smaller quantity of creosote per sleeper at about two-thirds of the cost. The reasons why the process was given up are not stated.

30. Regarding the employment of corrosive sublimate in India, the following information is given, in a report dated the 18th January 1870, by Colonel Kennedy, R.E., Secretary to the Government of Bombay, Public Works Department, Railway Branch (Public Works Proceedings, September 1877, No. 5).

An apparatus for Kyanizing sleepers was imported by the Great Indian Peninsula Railway Company, but none of the harder woods, such as Eyne (*Terminalia tomentosa*) and Erool (*Xylia dolabriformis*), used for sleepers, were treated under the process. A few soft-wood sleepers were Kyanized, and were found at the end of four years to be in good order. The process of Kyanizing in this country was discontinued, as the expense of preserving jungle-wood increased the price of the inferior timber to the price then being paid for teak. The iron apparatus used was also rapidly being destroyed by the mercury, notwithstanding the care taken in coating the iron with a protective substance. It is not stated what apparatus was used, and it is remarkable that iron was employed; for, in the ordinary soaking process, wooden tanks only are necessary.

31. The following information regarding the impregnation of sleepers with chloride of zinc for the Sind, Punjab and Delhi Railway is available.

The railway is divided into two sections—the Punjab section from Amritsar to Multan, and the Delhi section from Amritsar to Delhi. On the Punjab section, only unimpregnated sleepers were used, and they were embedded in thoroughly good brick ballast. On the Delhi section prepared sleepers were used, but they were embedded in an inferior ballast consisting of sand with only a light covering of broken bricks.

32. Mr. J. Harrison, Chief Engineer, Sind, Punjab and Delhi Railway, in a letter to the Agent, dated the 12th November 1869, stated that on the Delhi section all the wood-sleepers were deodar, with the exception of a small number of chir and sal. The deodar and chir were treated with chloride of zinc in two ways. Some were simply soaked in the solution at a temperature of 170° Fahrenheit for 4 hours, while others were subjected to the pneumatic process. The sal-sleepers received only a coating of tar. In 1875, the Agent communicated the result. On the Punjab section the renewals amounted in 8 years to about 1½ per cent. On the Delhi section the renewals amounted in 4 years to about 6 per cent. The Agent does not believe that chloride of zinc was very effective. He attributes the greater decay on the Delhi line to the bad ballast, but does not recommend that the impregnating process should be used again. Deodar is naturally a very durable wood, and it is remarkable that it lasted so badly in the Delhi section. Regarding the efficacy of chloride of zinc, the experience recorded admits of no reliable conclusions. The pneumatic process was only partially employed, mere soaking being also resorted to. In the Delhi section the ballast was acknowledged to be bad, and this section has a much greater rainfall than the Punjab section. The greater number of renewals on the Delhi section could therefore, under the circumstances, scarcely be said to prove the want of effect of the chloride of zinc on

deodar sleepers, while it proves nothing as regards the chir sleepers, because they were in the minority, and no special data regarding them are recorded.

33. The apparatus with which the pneumatic impregnation was carried out, was set up by Messrs. Brassey, Wythes and Henfrey at Phillour. It was afterwards, when in an imperfect state, offered for sale to the Forest Department by Messrs. Steel, McIntosh & Co., on the 1st of May 1874, for the sum of Rs. 11,750. The apparatus included three iron impregnation cylinders of 6 feet diameter and 28 feet length. The plates were nearly ½-inch thick. The cylinders had not the usual large moveable lids, but only small heads covering oblong openings of 4′ 1″ by 1′ 8″. The sleepers were put into and removed from the cylinders by coolies without the use of frames. The air-pump had a stroke of 22 inches, and a diameter of 13 inches, with india-rubber valves. The force-pump had a diameter of 3 inches and a lift of 16 inches. Three reservoirs made of deodar wood were placed below the cylinders. The solution employed by Messrs. Brassey, Wythes and Henfrey was a mixture of 1 part of chloride of zinc with 40 parts of water.

34. The following extract from the report of the Chief Engineer, Sind Section; Sind, Punjab and Delhi Railway, on the subject of Burnettizing sleepers is given by the Deputy Consulting Engineer for Railways, Sind, Kurrachee, in a letter addressed to the Consulting Engineer to Government of India for Guaranteed Railways, Lahore, No. 737, dated the 8th July 1878.

The works for Burnettizing sleepers were constructed at Kotree on the Indus in 1864-65. The cost for apparatus, sheds, &c., was Rs. 40,047. The cost of Burnettizing was Rs. 1-1 per sleeper. The work was stopped in 1867. The process adopted was as follows:—80 to 100 sleepers were thrown into a tank full of water mixed with about ½ cwt. of sulphate of zinc. (This is probably a mistake for chloride of zinc.) The sleepers were well boiled for 6 or 7 hours by means of steam passed through pipes fixed to the tanks for the purpose, and the sleepers were allowed to remain in the tank for 48 hours afterwards, no pressure being applied for injecting the liquor into the wood. The result is reported to have been most unsatisfactory. As an instance of the unsatisfactory result, it is stated that, when babool sleepers were brought down the line to Kurrachee and unloaded from the trucks, the bark of some came off, and not a particle of the process could be seen. This statement, of course, proves nothing. The above information is too summary to allow any deductions being made from it regarding the value for India of the operations now proposed. The apparatus set up at Kotree was apparently not a pneumatic apparatus, but the sleepers were only soaked in the solution. It is difficult to understand how so large a sum as Rs. 40,000 could be expended on such a simple business, and how the cost of the process could be as high as Rs. 1-1 per sleeper.

35. Some experiments with sulphate of copper appear to have been made on the East Indian Railway, for Mr. Sibley, in the letter of the 28th March 1870 already quoted (Public Works Proceedings, September 1871, No. 10), makes the following statement:—

"In 1866 a certain number of chir and deodar sleepers, which contained sapwood, were impregnated at Ghazeabad with a solution containing 3 per cent. of sulphate of copper under a pressure of 150lbs. per square inch. They were placed on the Jumna bridge at Delhi, and have stood well."

36. Boucherie's process of impregnating with sulphate of copper was employed at Palghat on the Madras Railway in 1865 and 1866. The solution containing about 1 per cent. of sulphate of copper was in wooden cisterns, fixed on a timber scaffolding, the bottom of the cistern being 20 feet above the level of the ground. The logs of timber impregnated were fresh from the jungle, they were cut in convenient lengths from 10 to 15 feet, and they were submitted to the process for 24 hours. At first the results were considered to be favourable. Captain Lindsay, R.E., Deputy Consulting Engineer for Railways, reported in May 1865 (letter from Deputy Consulting Engineer for Railways, No. 19, dated the 23rd May 1865, to Consulting Engineer for Railways, included in Government of India Circular No. 87, dated the 8th September 1865), that he had used prepared sleepers of certainly perishable wood which had been laid in the line in February, and which, when examined 3 months

afterwards, were untouched by rot, and had the edges as sharp as if they had been cut the day before. Captain Lindsay also reported that a pile of refuse wood prepared 9 months ago and lying in the yard, appeared to be perfectly sound.

37. But in October 1866 (Government of India Circular No. 3, dated the 3rd January 1867), the Acting Agent and Manager of the Madras Railway reported that the wood of numerous kinds which had thus been impregnated had split, and that a few kinds had been attacked by insects. A report of February 1866, by the Engineers entrusted with the enquiry, gives the following figures :—

Sleepers in good condition	7,143	68·1 per cent.
„ split slightly	2,802	26·7 „
„ „ badly	356	3·4 „
„ attacked by insects	184	1·8 „
„ rotton	6	0·1 „
Total	10,491	100 „

The woods belonged to 44 different kinds, all growing in the forests in the vicinity. But a few kinds only had suffered badly from splitting and insects.

The woods which had been injured most were—

	Pinay *Dillenia pentagyna.*	Pillaymurdoo *Terminalia chebula.*	Padree *Stereospermum chelonoides.*	Thawnee *Terminalia bellerica.*	Unnacarry *Odina Wodier.*
Good condition	2,000	1,928	100	600	400
Split slightly	2,068	75	112	120	217
„ badly	106	90	4	33	26
insects	...	5	1	150	17
rotton	...	4	...	...	...
Total ...	4,174	2,102	217	903	660

The woods which were most attacked by insects are *Terminalia bellerica* and *Odina Wodier*, two woods known to be extremely liable to the attacks of insects. Sleepers of these woods were bored to such an extent as in many cases to render them unfit for use. The insect was said to be a beetle, belonging to the family of *Bostricidae*. In the same way, those woods which have split are woods known to split readily, and it is not surprising that woods like *Dillenia pentagyna* and *Terminalia Chebula* had split. Sleepers impregnated with watery solutions of metallic salts will always be liable to split, unless dried with great care.

38. A further report was made to the Agent on the 3rd September, which stated that sleepers impregnated in the presence of the Engineers and buried soon after, were in good condition after having been in the line for 3 months, and had not been attacked, though they belonged to those kinds which are most liable to be attacked by the boring beetle (*Terminalia Chebula, Odina Wodier, Terminalia bellerica, Bombax malabaricum*). At the same time, these Engineers reported that the strength of the timber and its durability was rather lessened than increased by the process. Accordingly, the process was abandoned, and the Madras Railway reverted to the use of the sanctioned (naturally durable) kinds of wood for sleepers.

These reports prove that the protection afforded by Boucherie's process is not sufficient to preserve certain very perishable woods of the tropical forests of India against insects, and that woods thus impregnated are apt to split exceedingly. But the experience gained in this respect on the Madras Railway does not justify any conclusion regarding the effect of the pneumatic process with sulphate of copper and chloride of zinc on pine-wood from the Himalayas, with proper precautions to prevent the splitting of the wood.

39. In his letter dated the 18th January 1870, Colonel Kennedy states that in Sind, deodar sleepers were soaked in a solution of sulphate of copper, and stood well. Only 4 per cent. had rotted after 10 years, and none had been injured by white-ants. This, however, does not prove much in favor of sulphate of copper, as deodar is naturally a durable wood.

40. The results of the experiments made in India as here stated are not conclusive. Much money has been expended without adequate results, but it does not follow from the numerous failures which have here been recorded, that if persistent efforts are now made to impregnate timber in India with antiseptic substances, the result will not be favorable. But it is essential that only good and effective methods should be adopted, and that these methods should be employed under competent supervision, and should be continued sufficiently long on a systematic plan, to show in what respect they require alteration and improvement.

III.—Proposed plan of operations.

41. In the north-west Himalaya there are large extents of forests consisting of pines the wood of which, being less durable than deodar, has not hitherto been extensively exported to the plains. It is now proposed to utilize the wood of one of them, *Pinus longifolia*, for railway sleepers by impregnating it with metallic salts.

The sleepers to be impregnated will chiefly come from two sources—the forests on the Tons and Jumna, and those on the Alaknanda and Bhagirathi, and other feeders of the Ganges. Those from the Tons and Jumna rivers will be either impregnated at Rampur Mandi in Dehra-Dun, or will be floated down by the Western Jumna Canal, while those from the Ganges will probably have to be brought down by the Ganges Canal. It will probably be the best plan to set up impregnation apparatus at two places—one for the Tons and Jumna sleepers, and the other for those from the Ganges system. If this is done, it will be possible to establish the apparatus at the places where floating ceases; for the Western Jumna Canal this will either be at Jagádri on the Sind, Punjab and Delhi Railway, or at Delhi; or it might be possible to establish the apparatus at Rampur Mandi in the Dehra Dun, and from that place to cart the impregnated sleepers to *Saharanpur*, until the Chakrata Railway is constructed, which will afford an easy means of transit. For the supply from the Ganges the best locality will probably be at one of the points where the Ganges Canal crosses the Sind, Punjab and Delhi Railway, or where it crosses the Oudh and Rohilcund line, or at Barota on the Canal near Aligarh.

42. The area required for each factory will probably be about 10 acres. The present estimate is for duplicate machinery which may either be set up at one place, or which may be divided and put up in two distinct localities.

43. It is proposed to use the solutions of chloride of zinc and sulphate of copper, about 60 per cent. of the sleepers being impregnated with chloride of zinc, and 40 per cent. with sulphate of copper. This will furnish data for determining the relative merits of copper and zinc as preservative substances for sleepers on Indian railways. The plant proposed will be sufficient for the impregnation of 145,000 sleepers annually, on the supposition that the cylinders will be charged once only in 24 hours, and that there will be 250 working-days in the year. But, in order to leave sufficient margin for repairs and mishaps, the calculation of the working expenses will be based upon the supposition that there will be an annual outturn of 100,000 sleepers only. It is, however, obvious that, under favourable circumstances, and if the cylinders be charged more than once in 24 hours, the annual outturn may be increased considerably beyond the figure named, and that, in this case, the cost of impregnation per sleeper will be considerably reduced. It should here be mentioned that the present estimate is based throughout on the assumption that only broad-gauge sleepers $10' \times 10'' \times 5''$, containing 3·47 cubic feet each, will be impregnated. These data can, however, be made applicable to metre-gauge sleepers, 7 of the latter being counted for every 3 broad-gauge sleepers.

44. Sulphate of copper or blue vitriol will probably be imported in wooden casks from England, where its average cost is about £30 a ton. Sulphate of copper contains 36 per cent. of water of crystallisation, and 25 per cent. of metallic copper. The chloride of zinc of commerce is a heavy liquid which probably can be imported in strong casks; it contains 25 per cent. of metallic zinc, and it ought to be obtainable, on an average, at the rate of £10 per ton in England. The substances will be mixed with water in wooden tanks, which should be large enough to hold sufficient for four days' consumption.

45. There will be four cylinders, two of copper for the solution of sulphate of copper, and two of iron for the chloride of zinc. The copper cylinders should have an inner diameter of 5 feet and a length of 31·5 feet. The capacity of one cylinder will therefore be nearly 620 cubic feet, and it will contain a charge of 115 sleepers, the aggregate cubical contents of which amount to 391 cubic feet. The sleepers will be piled on frames of bronze running on low wheels, three of which will go into one cylinder. The estimate provides for 10 such frames, 9 of which will be in constant use at one time.

46. The two iron cylinders will have an inner diameter of 6 feet and a length of 31·5 feet; each of them will thus have a capacity of 890 cubic feet, and will take in a charge of 175 sleepers, with an aggregate volume of 600 cubic feet. The frames for these cylinders will be made of iron, and will also be 10 in number.

47. The sleepers having been rolled into the cylinder, and the lid closed, the air is exhausted and a partial vacuum maintained for several hours. (In several factories the pressure is brought down as low as 3lbs. per square inch.) After this the solution is permitted to enter the exhausted cylinder, the air-pump continuing to play for some time afterwards. When the gauge glasses show the cylinder to be nearly filled with fluid, the air-pump is stopped, the communication with the reservoir is interrupted, and the force-pump set to work, forcing the solution into the wood until a pressure of 120lbs. is reached. This pressure is kept up by pumping slowly or at intervals for as long as may be found necessary. The force-pump is then stopped and the communication with the reservoir re-established, so as to allow the remaining solution to run back; the lid of the cylinder is removed, and the impregnated sleepers are taken out, to be replaced by a fresh set, which should be ready piled upon the moveable frames.

48. By this arrangement it would be possible to impregnate two charges in 24 hours. Indeed, there are some factories where the cylinders are charged 4, or even 6 times, in 24 hours. The present calculation is, however, based upon the assumption that the cylinders will be charged once only in 24 hours, because it seems important that, at first, at least the impregnation should be as complete as possible, and this chiefly depends on the length of time the sleepers are allowed to remain in the cylinder. With one charge only, each copper cylinder will prepare 28,750, and each iron cylinder 43,750 sleepers in a year of 250 working days. Two pairs of cylinders, therefore, as previously stated, will turn out 145,000 sleepers a year. To drive the air-pumps and the force-pumps for 4 cylinders, a pair of engines of 5-horsepower each nominal will be necessary.

49. The whole plant to be purchased in Europe should be arranged in duplicate, thus affording perfect security against standstill through repairs. There are to be 2 steam boilers of 10-horsepower each. They are not to be tubular boilers, because these are more liable to get out of repair, but simple cylindrical boilers with one flue each, the whole to be set in masonry. The chimney is to be 75 feet high above the ground; chimney and foundation to be of solid masonry.

50. To each of the two steam-engines of 5-horsepower nominal, already mentioned, will be attached a full set of pumps, *viz.*, an air-pump, a copper solution force-pump, a zinc solution force-pump, and a small feed-pump; each engine and set of pumps being capable of doing alone the whole of the work required

from the 4 cylinders. The work may be distributed between the two engines either by working one at full speed to produce vacuum and to give the first supply of solution, whilst the other will be worked at slow speed to keep up the vacuum and the supply of fluid, or by allotting the air work to one engine and the fluid work to the other.

51. Although it is contemplated to begin with chloride of zinc and sulphate of copper, yet it is possible that, simultaneously with the employment of these substances, some sleepers may be impregnated by soaking them in corrosive sublimate. This salt has been employed with great success on several lines in Baden, Würtemberg, Bavaria and other countries in Germany; the solution is not forced into the wood under the pneumatic process, but is in wooden tanks which are filled with sleepers kept down by bolts or heavy weights. Should the establishment of a factory be decided upon, it will probably be advisable to make tanks for this purpose at once before the pneumatic apparatus is set up, so as to commence impregnating as soon as the first timber arrives at the factory. It will in every respect be advisable to test impregnation with this substance in India, but no special provision has been made for it in the present estimate.

52. It is also hoped that eventually it may be possible to manufacture creosote in Bengal, and for this substance the iron cylinders and other apparatus intended for zinc would then be available. It is also contemplated to make experiments with small quantities of wood-creosote or carbolic acid dissolved in the solutions of sulphate of copper and chloride of zinc. Sulphate of zinc, or white vitriol may also be tried.

53. We have also considered whether the creosote, which is obtained by the dry distillation of wood, might be used for the impregnation of sleepers. The chief products of this process, besides charcoal and inflammable gases, are tar containing a proportion of creosote and pyroligneous acid which is impure acetic acid with some creosote. By distilling the tar, impure creosote is produced, pitch remaining behind. In this manner a weight of creosote mixed with tar-oil, equal to about $2\frac{1}{2}$ per cent. of the dry wood, may be obtained.

But it is obvious that this substance can only be produced economically when the charcoal is made in closed chambers, so that the secondary products, *viz.*, pitch and pyroligneous acid, can all be preserved, and when there is a ready sale for them.

At Königsbronn in Würtemberg, a Mr. Lettenmaier has a factory in which he subjects beech-wood to dry distillation. He uses the pyroligneous acid for the manufacture of pure wood vinegar, and otherwise disposes of the valuable tar and other products. The inflammable gases aid in the process, and the charcoal is made over to the iron works at the same place, which belong to the State, and employ charcoal in the manufacture of the superior qualities of iron. Charcoal for the iron works is made also in the neighbouring forests from beech and pine-wood, but the primitive method pursued in the forest yields charcoal only, all other products being wasted. The wood used by Mr. Lettenmaier would be converted into charcoal whether he distilled it or not. His method of producing charcoal is, of course, a more expensive one than that employed in the forest, and he has to carry wood instead of charcoal from the forest to the works; but the sale of the other products—wood, vinegar, tar, &c.—well repays him for this.

In India, however, there is at present no chance of a sufficient demand on a large scale for charcoal, pitch, and pyroligneous acid to justify the expectation that wood creosote can be manufactured at a sufficiently low rate to be used for impregnation. As a matter of fact, this substance is nowhere used for the impregnation of wood in Europe. But the matter should be borne in mind with a view to the possibility of our employing creosote mixed with metallic salts.

IV.—Estimate.

(*A*) *Capital Outlay.*

Estimate for the establishment of a factory for impregnating railway sleepers of inferior pine-wood by the pneumatic process with sulphate of copper and chloride of zinc, capable of supplying annually 100,000 sleepers at least.

Purchases in England.

54. The rupee is taken as equivalent to 1*s*. 9*d*.

1. Two copper cylinders 31·5′ long, 5′ diameter; plates ¾ inch thick, double rivetted; with safety-valves, gauge-glasses, sparc plates, and rivets. Pressure 120lbs. (The factor of safety will then be 6·2.)

Weight, 23 tons .... £4,140 = Rs. 47,314

2. Two iron cylinders 31·5′ long, 6′ diameter; plates ⅝ inch thick, double rivetted; provided with valves, &c., as above. Pressure 120lbs. (The factor of safety will then be 7·8.)

Weight, 18 tons ... ... £900 = Rs. 10,286

3. Two steam-boilers, each of 10-horsepower, 16′ long, 4·5′ outside diameter, 2′ diameter of flue. Plates ½ inch thick. Pressure 100lbs., double rivetted. (The factor of safety will then be 10.)

Weight, 6·5 tons ... . £325 = Rs. 3,714

4. Two steam-engines of 5-horsepower each nominal, similar, each working four pumps: an air-pump, capable of exhausting 30 cubic feet of air per minute, with an average vacuum of 7·5lbs. per square inch; a force-pump of bronze, capable of forcing 3 cubic feet of copper solution in a minute, with 120lbs. pressure; a force-pump of iron, capable of forcing 3 cubic feet of zinc solution in a minute with 120lbs. pressure; a feed-pump, capable of supplying both steam-boilers with water.

Weight, 4·2 tons ... ... £320 = Rs. 3,651

5. Two bronze lift-pumps, which may be worked by hand or by steam with suction-pipes, each capable of lifting 3 cubic feet of solution per minute 15 feet high.

Weight, 0·2 ton ... ... £40 = Rs. 457

6. Two iron lift-pumps with pipes for the water-supply. Each of these pumps should be capable of raising three cubic feet of water per minute 30 feet high.

Weight, 0·2 ton ... ... £20 = Rs. 229

7. *Piping.*—Cast-iron piping for the air-pumps, 3 inches inside diameter, 100 running feet, with flanges, valves, &c. Wrought-iron piping for the zinc solution. From the reservoir to the zinc pumps, and from these to the cylinders, with flanges, &c., 300 feet of 2¼-inch bore. From the reservoir to the cylinders, 50 feet of 3-inch bore. Copper piping for the copper solution. From the reservoir to the copper pumps, and from these to the cylinders, with flanges, &c., 100 feet of 2½ inches outside diameter. From the reservoir to the cylinders 50 feet of 3½ inches outside diameter.

Iron weight, 2·2 tons ... ... £36 = Rs. 412
Copper „ 0·3 „ ... ... £54 = „ 617

8. Ten bronze frames for the copper cylinders—

Weight, 2·5 tons ... ... £400 = Rs. 4,572

9. Ten iron frames for the iron cylinders—

Weight, 3·5 tons ... ... £50 = Rs. 571

10. *Material of various kinds.*—Bolts and nuts, red and white lead, fire-hose, lightning conductor for the large chimney, tools, &c., &c.

Weight, 2·4 tons ... ... £121 = Rs. 1,383

Recapitulation.

		Tons.	£		Rs.
1.	Two copper cylinders	23	4,140	=	47,314
2.	„ iron „	18	900	=	10,286
3.	„ steam boilers	6·5	325	=	3,714
4.	„ „ engines	4·2	320	=	3,651
5.	„ bronze lift pumps	0·2	40	=	457
6.	„ iron „	0·2	20	=	229
7.	Piping	2·5	90	=	1,029
8.	Ten bronze frames	2·5	400	=	4,572
9.	„ iron fromes	3·5	50	=	571
10.	Material, tools, &c.	2·4	121	=	1,383
	Total ...	63	6,406		73,206
	Transport of material from England to site of factory, 63 tons at £8 per ton		£504	=	5,760
	Total cost of English materials, Rs. ...				78,966

Work in India.

		Rs.
55.	Clearing the ground and laying out roads on 10 acres	2,000
	Building a mud-wall as boundary	2,000
	Water-supply by well or canal	3,000
	A dwelling-house and accommodation for establishment	8,000
	Roof over the engines with walls, sheds in front of the cylinders, store-houses	2,000
	Drying houses for sleepers during the rains	3,000
	Chimney 75 feet high and foundations	2,000
	Masonry for steam-boilers	1,000
	Firebricks and fireclay	500
	Foundations for engines and cylinders	6,500
	Wooden reservoirs to hold 4 days' supply of solution, two large ones 16′ × 10′ × 10′, and four small ones 8′ × 5′ × 5′ inside dimensions...	3,000
	Retaining walls and digging for the large reservoirs	1,000
	Mounting of the whole plant	4,000
	Contingencies (5 per cent.)	2,000
	Total of work in India	40,000
	Total in England	78,972
	Grand Total	1,18,972

NOTE.—No provision has been made in the estimate for tramways, as the cost of these must depend on the locality where the machinery will be erected; but an allowance has been made under "working charges" to cover the cost of lead from the river or canal to the factory.

(*B*) *Working Charges.*

Estimate for the working expenses of a factory for impregnating sleepers by the pneumatic process.

56. The larger the number of impregnated sleepers turned out annually, the less will be the working expenses per sleeper. The plant is designed for the easy and perfect impregnation of 100,000 sleepers per annum, which number may be raised to 200,000 sleepers. The annual demand for sleepers on existing railways and on new lines in Northern India exceeds 500,000. In this estimate of the cost of working, an annual minimum outturn of 100,000 sleepers only is assumed. The first point to determine is the cost of the whole process, excluding the cost of the impregnating salts; and the second point will be the cost of the impregnating material for different degrees of the strength of solution.

	Rs.	Rs.
The capital outlay amounts to Rs. 1,18,972, the interest on which, at 10 per cent., including depreciation of plant, comes to		11,897
Lead of sleepers from the canal on the river to the yard, 100,000 sleepers, or 347,000 cubic feet at 40lbs. a cubic foot, give 6,200 tons. At 4 annas per ton per mile, for one mile gives		1,550
Transport of 1,00,000 sleepers from the yard to the cylinders and back, manipulation at the cylinders, 6,200 tons at 12 annas per ton		4,650

Establishment.

3 Engine-drivers, per mensem	120		
6 Firemen, „	90		
4 Cylinder-men, „	60		
1 Blacksmith and 1 carpenter, per mensem	30		
8 Daily labourers, per mensem	56		
1 Sweeper, „	8		
Working one well, „	60		
1 Darogah, „	70		
2 Munshis, „	50		
4 Watchmen, „	28		
4 Chaprassis, „	28		
Total per mensem ...	600		
Or annually		7,200	
Fuel for the engines, 6,150 maunds at 5 maunds for the rupee... ...		1,230	
Steaming and other experiments and unforeseen expenses		5,000	
Annual repairs to the plant		2,000	
Officers' salary		12,000	
Contingencies, travelling allowance, stationery, chemicals		2,000	
Total		47,527	

Or on 347,000 cubic feet, 2·19 annas per cubic foot or 7 annas 7 pies per sleeper. This is 2·87*d.* per cubic foot for the cost of the process only, against 1*d.* per cubic foot which is the average rate on railways in Germany. But it will be remembered that very liberal allowances have been made in this estimate in every respect, and that if the number of sleepers impregnated annually is increased (as it well may be), to 200,000 the rate will be reduced to 1·75*d.* per cubic foot.

57. *Cost of the impregnating material for different degrees of strength.*— Sulphate of copper landed at the works is estimated to cost £38 per ton, and, as this salt contains 25 per cent. of copper, one pound of metallic copper in the shape of crystallised sulphate of copper costs 12·4 annas. Similarly, the cost of one pound of metallic zinc in the shape of chloride of zinc may be estimated at 5·9 annas. The following statement gives the strength of the solution, the corresponding number of pounds of metal in 100 cubic feet of impregnated wood, the corresponding cost per cubic foot of impregnated wood, and, lastly, the cost of the impregnating material per sleeper of 3·47 cubic feet. It is assumed that one cubic foot of wood absorbs 16lbs. of solution.

Solution mixed in following proportions by weight.			Metal in 100 cubic feet impregnated wood.	Cost of Metallic Salts per cubic foot of wood impregnated with		Cost of Metallic Salts per sleeper of 3·47 cubic feet impregnated with	
				Copper.	Zinc.	Copper.	Zinc.
Salt.		Solution.	lbs.	Annas.	Annas.	Annas.	Annas.
1	in	80	5·0	0·6	0·2	2·1	1·0
1	in	53	7·5	0·9	0·4	3·2	1·5
1	in	40	10·0	1·2	0·6	4·2	2·0
1	in	32	12·5	1·6	0·7	5·3	2·5

Of the above proportions, the following are most likely to be used: Zinc 10lbs. and copper 7·5lbs. in 100 cubic feet of impregnated wood, corresponding to about one part of chloride of zinc in 63 parts of the solution by volume, and one part of sulphate of copper in 53 parts of the solution by weight.

58. For the solutions of this strength the following will be the cost of the whole process:—

	Cost of the Process only		Cost of the Metallic Salts only		Total cost of the whole Process	
	Per cubic foot.	Per sleeper.	Per cubic foot.	Per sleeper.	Per cubic foot.	Per sleeper.
	Annas.	Annas.	Annas.	Annas.	Annas.	Annas.
Zinc ...	2·2	7·6	0·6	2·0	2·8	9·6
Copper ...	2·2	7·6	0·9	3·2	3·1	10·8

Thus it will be seen that a broad-guage sleeper of 3·47 cubic feet will cost 9·6 annas to impregnate with zinc (10·0lbs. of metal in 100 cubic feet of wood), and 10·8 annas to impregnate with copper (7·5lbs. of metal in 100 cubic feet of wood). This is the cost under the supposition that only 100,000 sleepers are impregnated per annum. Should the number be doubled, then the cost per sleeper would only be about 8 annas for each of the metals.

Considering the liberal allowance which has been made in all respects in the estimate, it will be sufficient for all practical purposes to assume in round figures 8 annas as the cost of impregnating a broad-gauge sleeper with either zinc or copper, and half that amount for a metre-gauge sleeper.